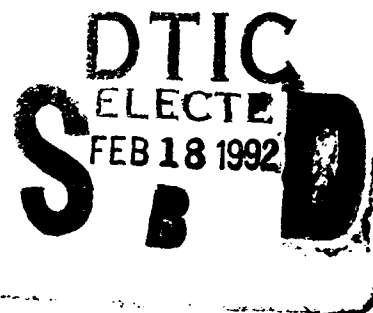AD-A245 977

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TASKING AND COMMUNICATION FLOWS
IN THE F/A-18D COCKPIT:
ISSUES, PROBLEMS AND POSSIBLE SOLUTIONS

by

Mark Francis McKeon

September, 1991

Thesis Advisor: Tung Bui

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by

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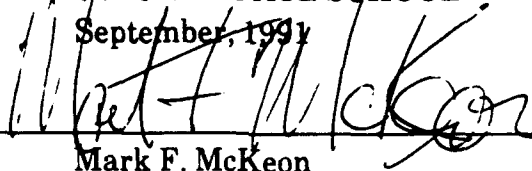of the requirements for the degree of

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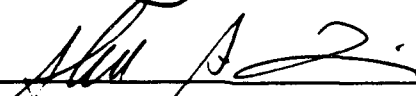NAVAL POSTGRADUATE SCHOOL
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ii

ABSTRACT

The U.S. Marine Corps is replacing its A-6E TRAM aircraft with the two seat F/A-18D. With the exception of the F-15E "Strike Eagle", never has a tactical aircraft been capable of processing such vast amounts of multi-mission data and displaying that fighter/attack information to the aircrew. These vast capabilities have led to some problems in the area of F/A-18D aircrew coordination. This thesis will review communication flows and tasking procedures that exist in many Group Decision Support Systems (GDSS) to develop guidelines that are applicable to tactical aircraft aircrew coordination procedures. These guidelines will then be applied to combat mission essential F/A-18D cockpit communication and tasking procedures that should be executed during various scenarios. Additionally, simulator flight profiles will be postulated to test, evaluate and verify these procedures. This study provides a framework on combat procedures that will not only benefit the Marine Corps' F/A-18D community, but as they start bringing into their inventory the two seat F/A-18E/F, the U.S. Navy as well.

TABLE OF CONTENTS

I. INTRODUCTION

A. OBJECTIVE OF THE STUDY

The primary focus of this study is to provide general
communication and tasking guidelines, developed from studies
on Group Decision Support Systems (GDSS), that can be
applied to aircrew coordination procedures in a combat
environment, regardless of aircraft type. This aircrew
coordination, the ability of the aircrew to process and pass
information (either verbally or through the computer) as
they perform a multitude of tasks (both combat and non-
combat related), must be executed flawlessly if they are to
be effective in combat. As an illustration, these
guidelines will be used to construct coordination procedures
for the F/A-18D aircrew associated with the "Hornet's"
various fighter/attack missions.

B. RATIONALE OF THE STUDY: THE CASE OF A F/A-18D CARRIER STRIKE MISSION

The purpose of this section is to provide a typical air
combat mission that illustrates communication and tasking
difficulties. To give the reader a better understanding of
the vast capabilities of the two seat F/A-18D, the
extraordinary dynamics of a multi-mission combat sortie, and
the complexity of effective aircrew coordination procedures

1

(concerning communication flows and tasking procedures), the following depiction of a carrier strike is provided.

Manning their aircraft, a F/A-18D "Hornet" armed with AMRAAM missiles and two 1000 lb Laser Guided Bombs (LGBs), Majors CASEY and MAC paused and took one last look up at the dark, early morning sky above the carrier. The clear air and twinkling stars gave hope that the weather forecaster's assessment of IFR conditions in and around the target area, which would preclude night visual operations, was incorrect.

Taxiing to the catapult, both aircrewmen reflected on the task which lie before them. Far to the North, in support of a feint, the rest of the air wing was to strike enemy positions along the coast. To the South lay the real target of the Marines' assault from the sea. The Gold River, running Eastward through the mountains towards the ocean, divides the enemy's land into a Northern and a Southern region. Two bridges span this river, over which the enemy has withdrawn one infantry division from the South to reinforce the coastal defenses in the North, where they feel the true attack will come. This shifting of forces has left only one division to defend the Southern region. Cutting these bridges would sever the lines of communication between the two regions and the enemy would be denied the ability to laterally move troops to reinforce the Southern region once the Marines commenced their assault. To counter Marine breakthroughs out of the established beachheads, the

Southern division would have to be reinforced within 48 hours of the initial landing. The success of the amphibious operation lie in the initial destruction of the two bridges.

The Hornet's mission was to slip away from the Northern strike group unnoticed; fly around, under or through enemy counter-air and anti-air assets undetected; to strike and destroy the two bridges.

After rendezvousing with the strike force and taking on fuel, Major CASEY backed the Hornet slowly off of the tanker. Once clear, he directed the nose of the F/A-18D to the Southwest, towards the Coast In Point (CIP). To ingress undetected CASEY had to get below the enemy's radar horizon, so he overbanked the aircraft and pulled down towards the sea, causing the Hornet to fall from the sky at a tremendous rate. Enemy radar operators on shore would see the strike force mass and proceed Northward; the lone blip, which was on their scopes only momentarily, would go unnoticed.

As CASEY brought the flight profile down in altitude Major MAC, the Weapons Systems Operator (WSO), momentarily turned on the radar to perform a quick position update on the CIP. After verification that the inertial navigational system (INS) was "Tight", the radar was silenced. In fact everything that could radiate from the aircraft was secured; there was little need to divulge their position to the enemy who was surely trying to detect and triangulate any threat emissions.

Both men were on Night Vision Goggles (NVGs) as they leveled off at 300 feet over the water. If the weather forecaster was wrong, the clear weather would allow Major CASEY to use both the navigational FLIR and his NVGs to locate and destroy the targets; Major MAC would assist in the navigational duties as well as maintain threat lookout. If the forecaster was correct, the weather in and around the target would preclude visual operations. They would have to navigate to the targets utilizing the Hornet's Search Radar Terrain Clearance (SRTC) capabilities. With these radar "Eyes", they would "See" the terrain 9 NM in front of the aircraft, and the two targets would be attacked through the use of one of the aircraft's radar system delivery modes. Having briefed and trained for every contingency, CASEY and MAC were prepared to meet either end of the spectrum.

Prior to going "Feet Dry" at the CIP, Major CASEY pushed the throttles up; accelerating to 420 knots at 300 feet. Their route of flight would take them over the low coastal lands, then into the mountains, following the valley that the Gold River snakes through. The first target lay 90 NM and 13 minutes ahead, the second 30 NM beyond that to the West.

The aircraft's radar warning sensors revealed that the enemy was diligently searching the night sky, overhead the Southern region, with their acquisition radars. Over these low lands, with nothing to conceal them, the F/A-18D was

most vulnerable to detection. Once discovered, the enemy
would relay the target data to its various tracking sites.
These tracking sites would provide the final firing
solutions to their respective AAA or SAM launchers.

Major MAC had plotted all known AAA and SAM sites on
their navigational charts and cockpit digital maps, their
route of flight avoided these positions. There would be
problems with mobile units, however, whose positions could
never be accurately ascertained. These systems lie in wait
as they process the relayed targeting data. When an enemy
aircraft has flown within range of these weapon systems,
their operators turn on the tracking radar, lock the target
up, and fire at point blank range. This "Quick draw"
procedure leaves the attacking aircraft with very little
time to react defensively. As the Hornet reached the
foothills leading to the mountains, still 65 NM from the
first bridge, this is precisely what transpired.

The radar warning receiver had given the crew
indications that an acquisition radar had picked them up
over the coastal low lands. It suddenly gave warning of
three quick "Paints" by a tracking radar system, and then
positive indication that the aircraft was locked up by a
mobile AAA gun unit forward of their right wing. Major
CASEY immediately broke the Hornet left and away from the
gun, dispensing chaff as he did and scanned the air for
tracers. Simultaneously, Major MAC turned on the aircraft's

electronic counter-measures in an attempt to foil the tracking radar's ability to automatically maintain lock, and visually searched for the gun's position.

The first series of tracers fell close behind the aircraft, very close. The second and third bursts gave evidence that the defensive actions had broken the enemy's lock on the Hornet. MAC called out from the back seat that there was high terrain 2 NM off the nose, to the right and CASEY immediately turned the aircraft right in the hope that, by utilizing the high ground for cover and concealment, he would deny the possibility of another radar track.

A second AAA site, this time forward and to their left, was using its tracking radar to search the sky in an attempt to reacquire the F/A-18D. During the first engagement the enemy had tracked them automatically, employing the AAA's computers to maintain lock on. It was the radar and these computers that the aircrew had beaten. There was little doubt in either airman's mind that all AAA site radar operators had now overridden the automatic tracking features of their systems and were running the system manually. The next AAA site might not be so easily fooled.

The Hornet's radar warning indicators showed that the enemy's search for them was closing in; it would be but a matter of seconds before the acquisition to lock up process would be complete.

"Stand-by to break right", MAC warned.

"Roger, give me a few seconds", was the response.

The transition from acquisition to lock on went smoothly. The gun's radar operator was in manual control of this firing, and as he studied his radar scope he was ever watchful for counter-measures and rapid changes in target aspect. As he slued the guns, just moments prior to trigger squeeze, he observed the aircraft's image on the radar screen fade into ground clutter and a "Lost track" light illuminate on his control panel. Round two went to the Americans, but he knew that whatever went in on a strike must come back out. If the Americans were foolish enough to use the same route of flight for their egress as they did on their ingress, he would be waiting.

The next four minutes went relatively smoothly; though the enemy was feverishly trying to acquire them, the mountains provided great cover. There was little need for emissions control now, so as CASEY navigated on NVGs, MAC turned on the Hornet's radar to search the sky above the first target. The enemy's fighters did not possess the capability to detect or shoot the F/A-18D down at the low altitude of 300 feet. They did, however, pose a great threat overhead the target. To deliver a LGB visually, the Hornet would have to climb to approximately 10,000 feet a few miles prior to the target. Having achieved the desired altitude, CASEY would immediately roll the aircraft back

over and plummet downward, designating the target to the aircraft's computer system in the dive. After designation, CASEY would hand off the laser tracking duties to MAC, who would then track the target, illumination it with laser energy, until LGB impact. Once MAC indicated that he was tracking the target, CASEY would release the LGB and pull the aircraft's vector up and away from Terra Firma. This pull up maneuver had to be executed carefully so as not to inhibit the WSO's track of the target with the laser designator and usually resulted in a high, arching turn. It was during this phase of the attack, from pop up to weapons impact, that the Hornet was most vulnerable to enemy fighter counter-air attacks.

Four minutes from the first bridge MAC picked up a section of enemy fighters on the radar orbiting 3 NM South of the target. As CASEY navigated through the valley, MAC tracked the hostile aircraft and continuously advised CASEY to their position. Both airmen knew that since the enemy was not deviating from their orbit points, the fighters would pose a definite threat to them when the Hornet was exposed overhead of the target. At 12 NM CASEY decided to launch an AMRAAM against the enemy's fighters.

As CASEY pulled the aircraft up to achieve the correct launch attitude he called "Shot out", warning MAC to divert his eyes from the bright flash of the rocket motor's ignition. Hopefully the missile would strike one of the

fighters, causing just enough confusion and indecision in his wingman to allow the Hornet crew to pop up, strike the target and slip away.

After missile launch, CASEY accelerated the Hornet. They were now less than a minute to pop up time and had the bridge in sight. Though there were two enemy fighters overhead the first target each crewmember knew that the attack had to continue. Hopefully, the one anti-air AMRAAM missile launched would strike home.

"Here we go", was CASEY's call as he turned Northward and pulled the aircraft into the high pop up maneuver. Simultaneously, the sky just South of the bridge lit up with a brilliant flash as the AMRAAM hit home.

"Roger, recorder, laser and counter-measures are on", was the reply.

As the Hornet climbed upward, MAC read off altitudes and airspeeds; CASEY maintained visual contact on the bridge and searched the area for any unfriendlies. At the predetermined roll-in altitude CASEY reversed the F/A-18D back down toward the target.

"Designate", was CASEY's call.

"Roger, standby . . . I've got it. Altitude", was MAC's reply indicating that he was tracking the bridge with the laser and that it would now be CASEY's responsibility to maintain altitude awareness. CASEY released the weapon and pulled up, searching the whole time for any hostile action

which might be taken against them. What seemed like an eternity later, the bright flash of a 1000 lb bomb detonating in a valley at night told CASEY it was time to get the aircraft back down on the deck.

"Looked good", MAC said as he turned off the recorder, which had video taped the first 20 feet of the bridge being destroyed.

They did not secure the electronic counter-measures, however, as the aircraft's radar warning indicators gave notice of an acquisition radar in the area. Passing 3000 feet the acquisition signals turned to one of a SAM lock on.

"SAM, left 1030, he's got us" MAC called from the back.

"I've got him" replied CASEY as he continued the descent, "I'm going to cross the mountains to the North and hop into the next valley."

Moments prior to ridge line crossing the radar warning indicator went to "MISSILE LAUNCH" and MAC visually acquired the SAM leave its rail and proceed towards the Hornet.

Using MAC's calls on time remaining and missile distance, CASEY knew that he would make the ridge line prior to missile impact. Once across, he would mask the Hornet from the tracking radar by descending down to the valley floor, turn Westward and advance up the valley until such time as they were able to again cross the ridge line and strike the second bridge. "We've got it made" was CASEY's call as he crossed the ridge line and pushed the aircraft

down into the forecasted bad weather that lay unseen in the
Northern valley.

Neither aircrewmen would see the SAM impact the ridge
behind them as CASEY cried out "Radar, radar, radar"
indicating that both men must come off visual cues of
navigation and go to the aircraft's SRTC mode of operation.
Their choices were simple: Either to climb up and above the
bad weather and into the fighter/AAA/SAM weapons envelopes
or to stay low and adjust very quickly to flight utilizing
the radar and flight instruments.

Scopes had to be brought up, switches had to be turned,
buttons pushed. Most importantly, however, was the fact
that both aircrewmen had to immediately switch their mind-
set towards that of flying night, low level SRTC in the
mountains with the aircraft's radar acting as their eyes.
At 20 NM from bridge number two the transition was complete
and CASEY leveled the Hornet at 350 feet and 420 knots.

CASEY was flying the aircraft off of the synthetic
video that the aircraft's computer provided as a depiction
of the terrain in front of the Hornet; MAC was reading the
raw video of the aircraft's radar. At 7 NM from the target
there was a saddle in the ridge line, which ran off forward
of their left wing, over which they could slip undetected.
Both aircrewmen knew that the weather would not support
another visual attack; the strike on the second bridge would

have to be a radar system attack, utilizing a level lay down delivery.

It was MAC's responsibility to verify that the aircraft's flight profile was always clear of the mountains or other obstacles, so as CASEY climbed and turned the aircraft left MAC's main focus was on the ridge crossing. The call "Level off" from the back told CASEY that the aircraft had sufficient altitude to clear the ridge line.

Crossing the ridge line at 200 feet, CASEY turned the Hornet back to the right, towards the second bridge, and climbed to stay out of the 1000 lb bomb's fragmentation pattern. The enemy was still trying to acquire them, so as MAC placed the radar cross hairs on the Southern end of the bridge, he also turned on the electronic counter-measures and the mission recorder. Due to the bad weather the mission recorder would not be able to record the actual hit as it had done on the first bridge, but it would verify weapons release on the target.

As CASEY leveled the Hornet in altitude 3 NM from the target, the enemy's acquisition radars were getting close to locating them. Both crewmembers knew that it did not matter now, they were to close to the target: No matter what else happened, they would attempt to press this run to completion.

Seconds from release, CASEY brought up the radar display of the target, verified target track, and committed

the automatic weapons release features of the aircraft. At
weapons release a SAM tracking radar to the North came up,
so CASEY broke the aircraft left. They would cross the
ridge line to the South, dive for the valley floor, and make
their way Eastward to the sea. Once again, the cat and
mouse game was on.

Reconnaissance photographs of bridge number two
revealed that though not destroyed, it had suffered
structural damage that would require three days to repair.
That would be a day and a half after the Marine's broke out
of their beachhead.

C. INFORMATION OVERLOAD AND PROBLEMS WITH AIRCREW COORDINATION

The proceeding scenario is of course fictitious. The
flight of Majors CASEY and MAC was developed to illustrate
two important points. First, there are very few tactical
aircraft in the world today that can process the quantity of
data, or display the amount of information, that the F/A-18D
can. The Hornet's information generating abilities will
only increase as upgrades to the aircraft's computer and
radar systems are incorporated allowing the F/A-18D to
become the all weather strike fighter described in the case.
Second, the Hornet's vast capabilities has led to some
problems in the area of aircrew coordination. Orchestrating
the task sharing and information flows that would be

13

required to successfully complete a difficult mission, such as the one portrayed, is a complex process.

   .·The F/A-18D community, both pilot and WSO, is composed of aircrew drawn from other aircraft communities: F-4, RF-4, A-6E, EA-6B, F-18 and OV-10. Each aircrewman brings along with him preconceived notions and beliefs as to what the roles of the pilot or WSO should be based upon past experience in their respective communities.   But the F/A-18D is not an upgrade to the A-6E, nor is it a super F-4S. To think of the F/A-18D in these terms is to limit its capabilities.

   If the full potential of the F/A-18D is to be realized mission essential cockpit communication and tasking procedures must be developed that transcends personal bias or opinion.

D. RESEARCH OVERVIEW

   The following is provided to familiarize the reader with the various research issues that will be covered in my paper. The work will be broken down into four main areas of research or discussion topics. Each of these topics will be briefly outlined.

   First, a brief MIS literature review will be conducted on intra-group communication and tasking within a Group Decision Support Systems (GDSS). This review will build the foundation for the research.

Second, the computer supported collaborative work done by the two aircrewmen in the F/A-18D, specifically in the areas of tasking and communication flows, will be explored. Although all F/A-18D missions will be examined, primary emphasis will be placed upon the Visual Night Attack role (utilizing NVGs, a capability which the aircraft currently possesses) as well as a projected All Weather Attack role (utilizing up-grades to the aircraft's radar and computer systems to provide this capability).

Third, a proposed research design, centered around the F/A-18D simulator, that would evaluate and verify the proposed procedures, tasks and communication flows, will be briefly outlined.

Fourth, a discussion of further research areas that this study has revealed will be conducted.

II. LITERATURE REVIEW

This chapter will explore various research conducted on Group Decision Support Systems (GDSS), specifically in the areas of intragroup communications and tasking, to see if they are applicable to the kinds of computer supported collaborative work done by the two aircrewmen in the F/A-18D. If an examination of individual and collective tasks is to be effectively undertaken later in this study, a review of this material is essential in creating a basis or foundation from which to conduct that research.

A. GDSS AND THE F/A-18D

The first spe·ific question to answer is "Can research in GDSS be applied to the F/A-18D?"

A GDSS can be defined as a computer-based system that aims at supporting collective problem solving. "A collective decision-making process can be viewed as a problem-solving situation in which there are two or more persons (i) each of whom is characterized by his or her own perceptions, attitudes, motivations, and personality, (ii) who recognize the existence of a common problem, and (iii) who attempt to reach a collective decision" (BUI & JARKE 1986).

Certainly the F/A-18D fits well within this definition of a GDSS, where collective decision-making processes are performed by the two aircrewmen working in their respective cockpits or "Individual workstations". To support this collaborative work each cockpit is linked together through communication channels (via the ICS and radio) and data flows (via a central computer which provides decision support). It is these communication and data flows which supports the two seat Hornet's aircrew coordination and tasking procedures.

This leads to a second question "Is a GDSS the appropriate set up (and hence applicable to this study) for the cockpit of the F/A-18D?" The answer to this lies in the types of combat related problems that the F/A-18D aircrew face in relation to the Suchan, Bui, and Dolk Contingency Model of GDSS use. This model (Figure 2.1) focuses on the relative effectiveness of GDSS use in relation to two general problem types, either 'task' or 'relationship' (BUI 1987).

Task-oriented problems require precise, linear thinking. These problems are usually well defined, technical and highly structured often requiring the analysis of significant amounts of data (BUI 1987). In combat situations, the two seat Hornet aircrew are faced with solving high task-oriented problems.

17

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        High    GDSS not          Discretionary
                recommended       GDSS Use

                   IV                 III
RELATIONSHIP

                GDSS not             GDSS
                recommended       recommended

                    I                  II
        Low

                Low        TASK       High
```

Figure 2.1: Contingency Model of GDSS Use

Relationship-oriented problems are relatively unstructured problems. They call for empathetic thinking rather than merely analytical thinking (BUI 1987). Though there are times when a "Gut" reaction is required during air combat missions, most F/A-18D problems are towards the lower end of the relationship-oriented scale.

The Combination of these two problem types, high task-oriented and low relationship-oriented, places the cockpit of the F/A-18D in Section II. This section of problem types recommends the use of a GDSS to support problem solving activities and hence a GDSS structure is highly desirable in the F/A-18D.

18

B. STUDIES IN COMMUNICATION

Intragroup communication, in a GDSS environment, can be categorized as either non computer-mediated or computer-mediated. Each category contains different communication paths and those paths which are relevant to the F/A-18D cockpit will be discussed below.

Non computer-mediated communication is that communication which occurs through media other than computer-supported media (LIM & BENBASAT 1990). It is the direct, face to face interface of participants (Figure 2.2). This form of communication can be divided into two paths, either verbal (spoken) or non-verbal (visual cues or signs) (LIM & BENBASAT 1990).
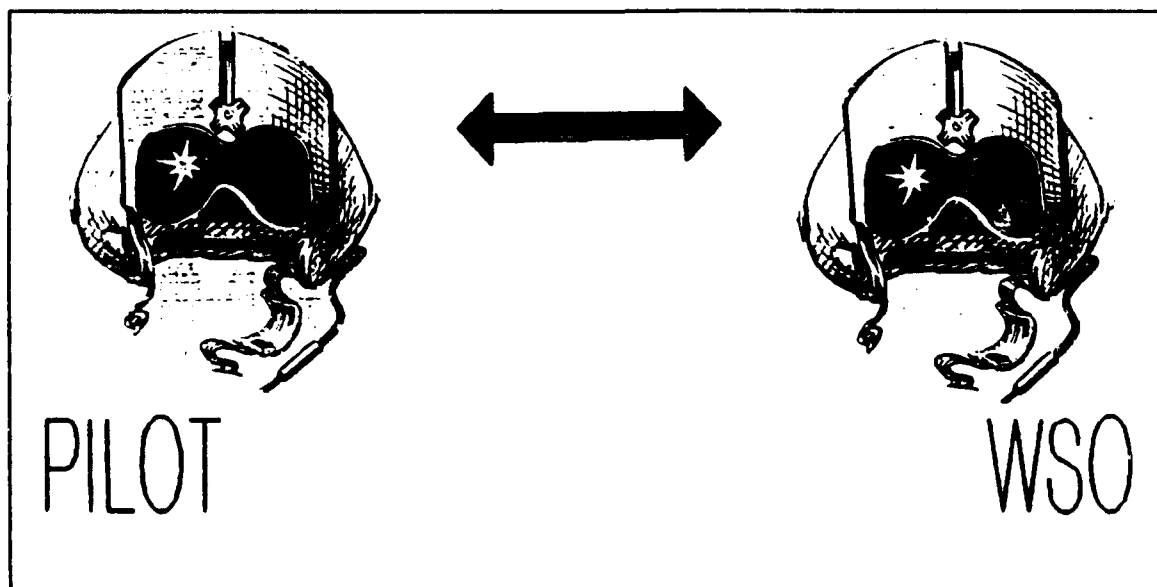
Figure 2.2: Non-Computer Mediated Communication

The F/A-18D's ICS, and to a lesser extent the UHF
radio, readily supports the verbal content of spoken
communication and the accompanying paralinguistic cues (e.g.
loudness, rate of speech, tone, pitch changes, pauses) (LIM
& BENBASAT 1990).

The F/A-18D, like other tandem seat aircraft (Vice
aircraft designed with Side-by-Side seating, like the A-6E)
does not readily support non-verbal communication. The
ability of either the pilot or WSO to convey non-verbal hand
or head messages is limited. Signals can only be seen or
given in the space between the WSO's instrument panel and
the canopy (Figure 2.3).
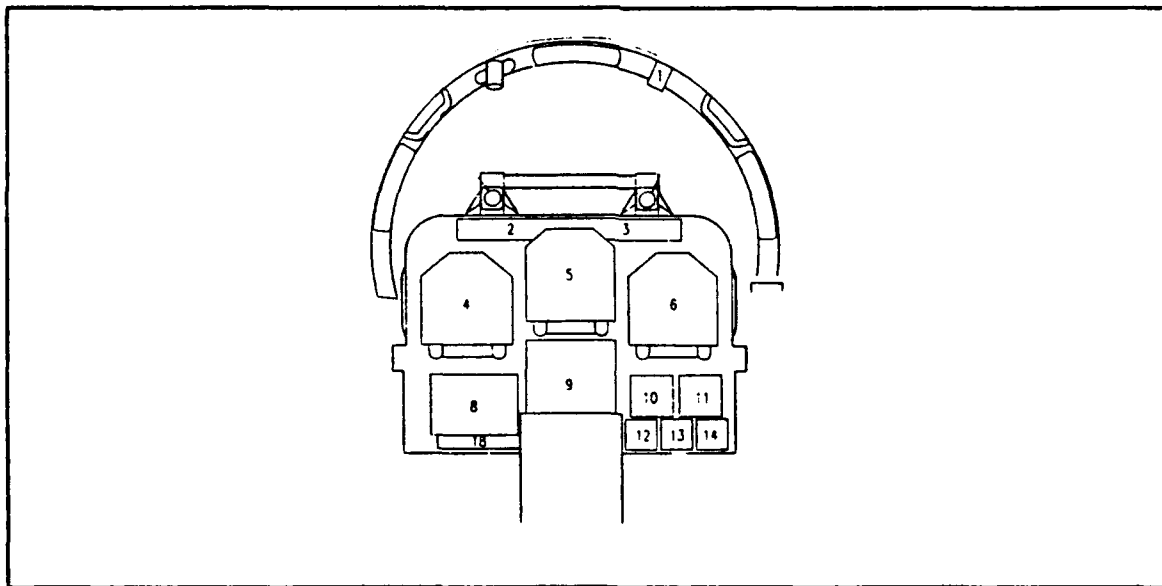
Figure 2.3:   Non-Verbal Limitations

There are two types of computer mediated communication
paths which the F/A-18D supports (LIM & BENBASAT 1990).

These paths are: (i) Central Computer -> Participant and
(ii) Participant <-> Workstation <-> Central Computer <->
Workstation <-> Participant (Figure 2.4).
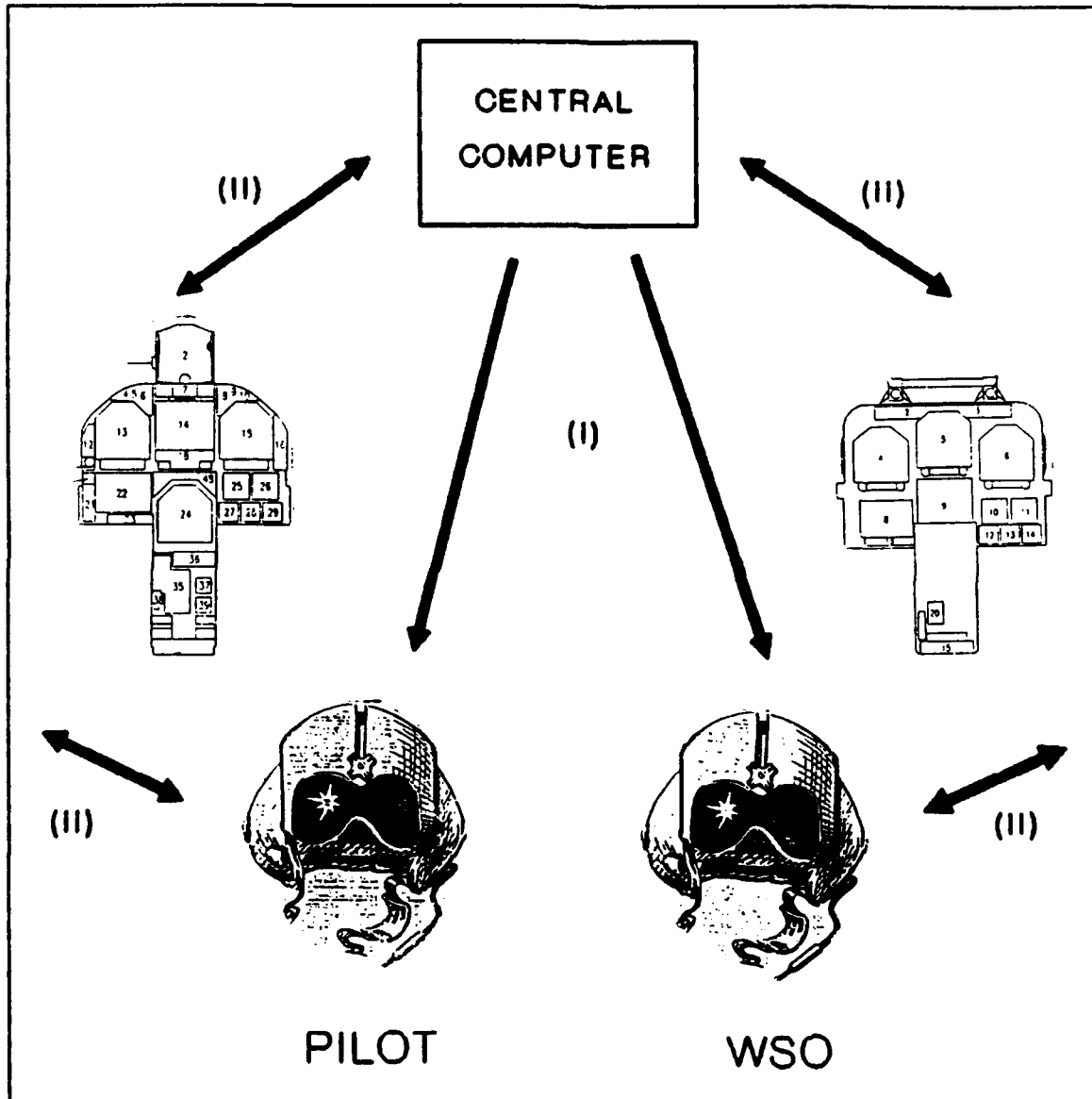
Figure 2.4: Computer Mediated Communication

Path (i) is where the central computer, monitoring
avionics and sensor systems, communicates directly to the

21

aircrew. This communication flow takes the form of audio and visual warning signals and is activated only when certain emergency situations, like engine fire, exists.

Path (ii) is where the participants communicate with each other, through the central computer, via their respective workstations or cockpits. Most of the Hornet's computer mediated communication travels via this path. As this type of communication and data flow support the Hornet's combat aircrew coordination procedures, further examination of this path is warranted.

C. THE FOUR MODULES OF THE COMMUNICATIONS COMPONENT

The four modules of the Communications Component model can be utilized in the examination of the F/A-18D's computer-mediated communication flows   (BUI 1987).   Three of the model's modules will be discussed separately.

1. Group Norm Constructor

The purpose of the Group Norm Constructor is to allow the definition of a flexible and adjustable mechanism for monitoring communication and information transfer between individual DSSs. The Group Norm Constructor defines communication channels, information parameters, and group decision structures/rules. This functional specialization aids a decision group in defining a framework for computer-based group decision making where the GDSS does not know in

22

advance which type of communications should be invoked in a specific group decision situation (BUI 1987).

2. **Group Norm Filter**

The norm generated by the Group Norm Constructor is compiled into a set of enforcement routines called the Group Norm Filter. The function of this module is to enforce the defined protocols whenever a communication activity is triggered by the GDSS user (BUI 1987). Specifically it performs this function through granting user access, data transfer recording and monitoring computation of group decision results (BUI 1987).

3. **Invocation Mechanism**

This module enables decision makers to request a modification of the communication protocols. The rationale of such a mechanism is to provide enough flexibility to deal with the inherently dynamic and nondeterministic nature of group problem-solving processes. The Invocation Mechanism also permits creation of incremental changes and multiple alternate norms (BUI 1987).

At a most rudimentary level the decision support structure of the F/A-18D models this four modules of the Communications Component concept. The Hornet's aircrew does not have the flexibility to input norms nor develop the structure of the decision support system. This model plays a far more dynamic role in a GDSS environment than it does

in the cockpit of the F/A-18D. But the basic structure of
the model is in place; the F/A-18D's decision support can be
viewed along the lines of these basic modules.
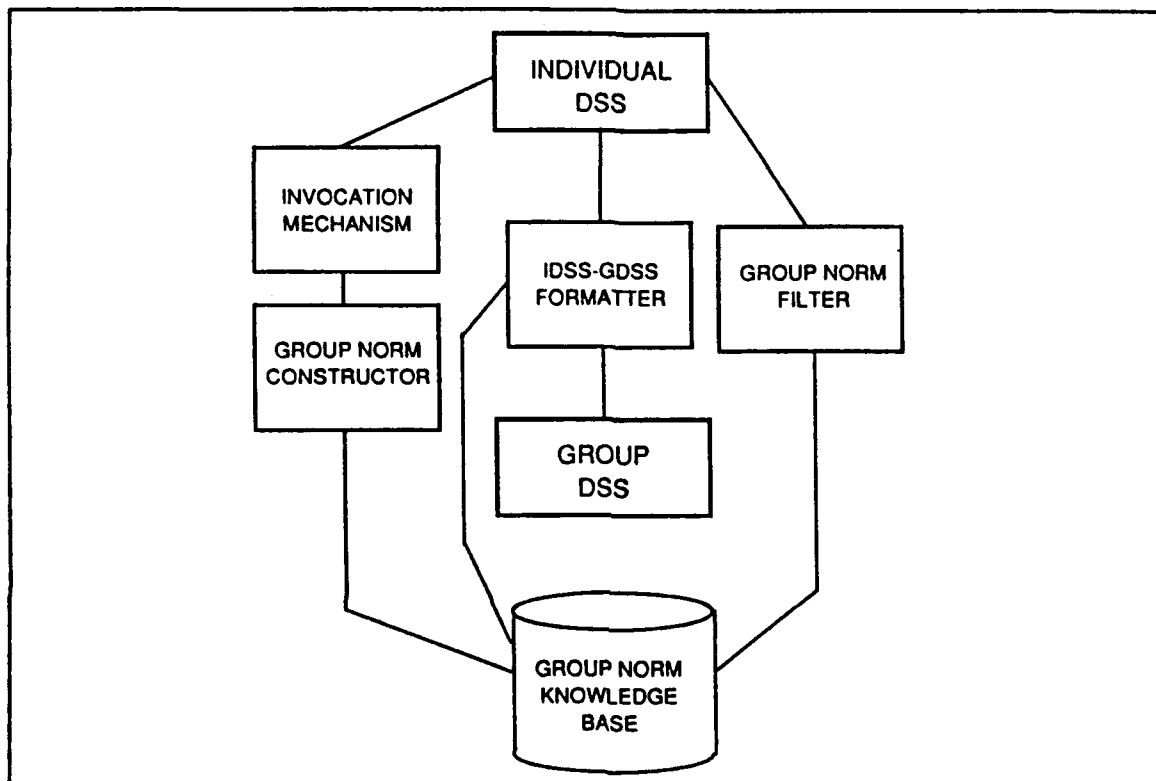
Figure 2.5: The Four Modules of the Communications Component

        The following section examines GDSS tasking studies
and contains a proposed goal/tasking model for combat
aircrew coordination procedures. Because the F/A-18D's
computer system only marginally performs the functions
associated with each module of the Communications Component,
these proposed tasks can be thought of as being "Manual"
procedures. For example, if an aircrewman is tasked with
performing a radar search for enemy aircraft he must select

the air-to-air DDI display, conduct a search pattern and monitor/process the information.

D. STUDIES IN TASKING

Research has been conducted concerning the study of group tasks and resource allocation. While these studies provide a valid framework in the examination of tasks performed by groups, and can be extended to a GDSS environment, they do not lend themselves easily to a study of the tasks performed in the F/A-18D. In their study on team training Salas et al. (1990) reviewed much of this research and categorized it into these general approaches: (i) Hackman's Normative Model which assumes that organizational context and group design (i.e., input variables) affect the members interaction process which ultimately plays a direct part in shaping the quality of team performance (i.e., output variables); (ii) Gersick's Time and Transition Model which describes how a team initially establishes a method of task performance and how they reevaluate those methods midway through the allotted time frame for task completion; (iii) Gladstein's Task Group Effectiveness Model which states that the degree of group effectiveness, (i.e., a group's terminal performance and its satisfaction with the job done) are a function of the elements of group process (e.g., open communications, discussion of strategy, weighing individual inputs)

moderated by the group task demands; (iv) Morgan et al. Team Evolution and Maturation Model which suggests that task-oriented teams evolve through a series of developmental phases; (v) Dickinson's Task-Oriented Model which emphasize that team performance is a function of the sub-tasks that members must perform effectively for the accomplishment of team goals. Further, Dickinson suggests an analysis of the performance requirements of these sub-tasks to indicate the relative emphasis that should be given to individual and team skills training (SALAS ET AL. 1990).

Discussions held with Dr. Salas revealed that each general approach was not applicable in its entirety to a study of Hornet aircrew tasking procedures. The model whose elements most closely parallels that required to perform the study at hand is Dickinson's Task-oriented model. According to the Task-oriented model developed by Dickinson and his colleagues, an analysis of performance requirements involves the examination of interrelated aspects of task structure, work structure, and communication structure (SALUS ET AL. 1990).

Task structure is described by the complexity and organization of the sub tasks to be accomplished. Task complexity deals with the demand characteristics of the sub tasks. Task organization refers to the interdependencies that exist between various sub tasks of a team task (SALAS ET AL. 1990).

The work structure of a team refers to the manner in which sub tasks are assigned to and shared by various team members (SALAS ET AL. 1990).

The communication structure of a team consists of patterns of interaction between team members that develop as a function of task organization, task complexity and work structure (SALAS ET AL. 1990).

There are three main reasons these approaches do not transfer easily to a study of the F/A-18D. First, the goals and their associated tasks are known before the collaborative work is performed; something that rarely happens in a team or GDSS environment. Second, psychological elements, such as egos and motivational factors, do not play much of a role in cockpit group decisions. Lastly, the group decisions that the aircrew are faced with take place in a dynamic and rapidly changing environment, unlike any other. These group decisions, in a combat situation, literally carry with them life and death consequences. Each of these approaches does contribute, however, something to this studies proposed tasking model.

The following model for task analysis is proposed and will be utilized in the examination of the various missions that the F/A-18D may be called upon to perform. It contains four elements: The goal, primary tasks, sub-tasks and supportive tasks. The model is also applicable to other aircraft and group decision environments where goals and

27

critical tasks are identified prior to the commencement of the activity.

1.   The goal

The first element of the model is the goal. This element has two important considerations. First, though there can be more than one goal of the unit, these goals can not conflict in time (Only one goal may be pursued at any given time). An example of goals and goal switching can be seen in the introduction's fictitious story. Because the F/A-18D is capable of flying multiple missions on one sortie, there can be multiple goals over the span of the flight. The goal of destroying the first bridge was superseded by the goal of self defense when the Hornet was fired upon by the enemy's mobile AAA. Only when the goal of self defense was achieved, and the tracking solution of the enemy's guns defeated, could the switch back to the original goal be undertaken.

Secondly, it is the participants (aircrew) themselves that set the priorities of the goals. Again, an illustration from the story. The aircrew had decided that the goal of destroying the second bridge (or at least trying to) had priority over that of the goal of self defense. Even if the Hornet was to be fired upon, CASEY and MAC committed themselves to attempting the second bombing run.

2. Primary tasks

The next element in the tasking model are the primary tasks which must be successfully completed to obtain the desired goal. Again, this element contains important considerations. First, these primary tasks may be accomplished through either individual effort or group action. Again, drawing from the story. The Hornet's goal of destroying the first bridge can only be achieved if Major CASEY successfully navigates the aircraft to the target, avoiding all hazardous terrain (individual), and the target is correctly identified and tracked (group).

Second, the responsibility for the execution of a primary task can be assigned from one crew member to the next. As an example, the primary task of tracking the first bridge, during the dive to deliver the LGB, was handed off by Major CASEY, through the computer, to Major MAC for execution.

Third, unlike goals, there may be multiple primary tasks being conducted at any given time, either individually or collectively as a group. As Major CASEY navigated to the target and performed terrain avoidance duties he was executing two individual primary tasks. An example of group multiple task execution was when Major CASEY was utilizing the SRTC for terrain avoidance and Major MAC was using the radar for navigation, terrain avoidance and target identification.

Fourth, primary tasks can also be assigned priorities or order of precedence. If, during the attack on the second bridge, MAC would have been unable to accomplish the primary task of acquiring the bridge on the radar, Major CASEY would have had to have come off of his primary task of terrain avoidance and assist in the target acquisition duties. This leads to the fifth consideration, downgrading the primary task.

In the example just cited, if the target is not acquired on radar the aircrew will not successfully achieve their goal; nor will they achieve their goal if the aircraft crashes into the ground. How can either primary task be forsaken without degrading mission effectiveness? The only way this can be accomplished is to downgrade one of the primary tasks. Continuing with the example. The primary task of acquiring the bridge on radar can not be downgraded. If the bridge is not identified on radar it can not be attacked given the poor weather conditions, and the goal will not be achieved. But, a simple change in altitude will allow the primary task of terrain avoidance to be downgraded to that of a lesser task. At 300 feet Major CASEY has little room for error in his terrain avoidance duties, and must focus much of his attention to that task. At 3000 feet his room for error is much larger, and he can now direct his attention towards the direction of helping the group achieve the goal.

3. Sub-tasks

Supporting the primary tasks are sub-tasks, which can only be pursued when the primary tasks are being successfully handled or conducted. They have the same five considerations as discussed in the primary task section. Sub-tasks are also critical to goal attainment, though they are not as important as primary tasks and their activity must be terminated should the successful accomplishment of the primary tasks be in doubt. An example of a sub-task performance is Major MAC's scan of the radar warning receiver during the ingress to the targets. Major CASEY would be performing the primary tasks of navigation and terrain avoidance predominately with his "Head" out of the cockpit on NVGs. He might miss critical cockpit warnings of enemy threat systems. It is the responsibility of Major MAC to undertake this sub-task. If, however, Major CASEY can not accomplish one of his primary tasks, for example target identification, MAC must discontinue the execution of all sub-tasks and aid in the achievement of the primary task at hand.

4. Supportive tasks

The last group of tasks to be proposed are supportive tasks. These tasks aid in the overall effectiveness of the group, but the inability to perform these tasks does not degrade from the achievement of the

goal. An example of this type of task would be Major MAC turning on the mission recorder during both bombing runs. The taping of the LGB impacting the first bridge aids intelligence personnel on assessing bomb damage, but the bridge would still have been destroyed with or without the mission recorder being on.

A question that arises is "With the four modules of the Communications Component model and the proposed goal/tasking model as a frame of reference, can the F/A-18D's computer system increase its role as an aid in aircrew decision support?" To answer this two areas need exploration.

E. MODULE DESIGN CONSIDERATIONS

First, where would the system designers place the algorithms necessary to increase the role of the F/A-18D's central computer in decision support matters? Simply stated, in the Group Norm Constructor, Group Norm Filter and Invocation Mechanism module concept previously discussed.

Second, what would these system designers incorporate into the software upgrades to provide better decision support? The answer lies in the relationship that exists between the modules of the Communication Component model and the proposed goal/tasking model. This would then be coupled with the desired system outputs, or levels of support, that

the aircrew should receive as decision support inputs.
Concrete recommendations are provided in section G.

F. FUNCTIONAL REQUIREMENTS FOR A AIRCREW COORDINATION SUPPORT SYSTEM (ACSS)

1. System Overview

In the previous section we identified some generic
functions of the modules cf the Communications Component in
a F/A-18D. This section addresses a number of guidelines or
functional requirements that would help system developers
efficiently analyze, design and implement a computer-based
system to support aircrew coordination. The coordination
system should be fully integrated into existing aircraft
computers to enhance the decision support capabilities. The
primary purpose of such a system (Aircrew Coordination
Support System, ACSS) is to enhance the decision support
capabilities of aircraft computers (Figure 2.6).

As an integrated module, special considerations
should be given to interface the ACSS with existing sensory
devices. Stimuli for decision support activities could come
from external or internal sources. Enemy radar emissions
are typical external sources. Designers must know not only
what sensors the system is interfaced with, but also those
that it could be tied into. The system must not require its
own interface with the aircrew. Instead, it should use
existing DDIs as a vehicle to communicate with the aircrew.
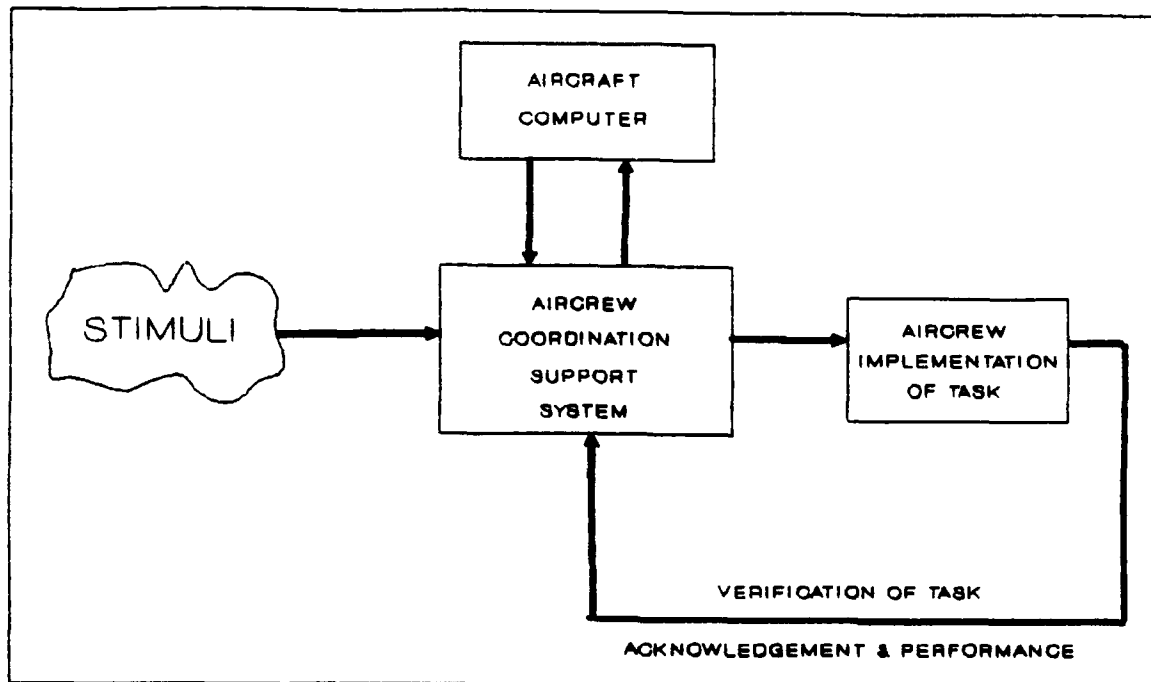
Figure 2.6: Aircrew Coordination Support System (ACSS)

In a confined environment, designers must know what systems the computer is or could be interfaced with to produce the desired results.

2. The Three Levels of Decision Support

There are three levels of decision support that an ACSS could provide, and hence a designer could develop. Each is not mutually exclusive, the ACSS could provide Level 1, 2 and 3 decision support at the same time. A discussion of each, with examples, follows.

a. *Level 1*

Level 1 decision support activities are those which control single systems. This releases the aircrew from the physical task of having to do so. Level 1 support

provides no directive or descriptive guidance. An example
of Level 1 support would be for the computer to
automatically "Bring up" the air-to-air radar scope (though
not manually selected) on the low priority DDI when a
certain predetermined threat condition exists.

b. Level 2

Level 2 decision support activities controls
either a single or multiple systems and provides some basic
directive guidance. An example of Level 2 support. The
ACSS of an F/A-18D, armed with both bombs and HARM (High
speed, Anti-Radiation Missile), conducting a strike mission
senses the presence of a threatening enemy SAM radar
emission. Instantly, the ACSS provides visual warning
indications to the aircrew, switches the weapons release
mode to air-to-air (thus allowing the pilot to rapidly fire
the HARM should he decide to do so) and provides steering
information to the pilot's HUD directing him to the optimal
firing position.

c. Level 3

Level 3 decision support activities provides both
directive and descriptive guidance. An example would be for
the ACSS to flash the radar image of the air target that
possess the greatest threat (set on some predetermined
criteria, entered by the aircrew, such as closing velocity,
altitude, etc.). Another example could find the ACSS giving

35

steering commands to the pilot's HUD (or vectors on the moving map display) that would direct the aircraft out of the enemy's radar envelopes based upon an analysis of the current levels of threat emissions and known threat positions.

If the structure is in place to allow the F/A-18D's computer to increase its role as a decision support tool, can a framework for that software development be constructed?

G. F/A-18D COMPUTER GENERATED DECISION SUPPORT

The Group Norm Constructor module would contain the group goals and their respective priorities. Entered through the Invocation Mechanism module, these goal priorities could have a default value or the aircrew could set their relative weight/value according to enemy threats.

Inputs could be entered into the ACSS, by the aircrew, through two methods. First, through a menu driven application conducted during preflight operations. Second, through the preflight loading of a programmed mission cassette tape.

The concept of goal switching could also be imported into the system based upon pre-flight consideration such a aircraft position or time.

The Group Norm Filter module would contain the various primary tasks, their relative priorities, which aircrew the

primary task(s) is assigned to, the required DDI display for

successful task execution (according to the goal being

conducted by the aircrew) and DDI display priorities.

Again, these inputs would be entered by the aircrew, through

the Invocation Mechanism, prior to the flight. The output

of the Group Norm Filter would be one of the three levels of

decision support.

To illustrate these concepts the following is developed

to depict how software upgrades to the F/A-18D would aid in

its decision support capabilities.

H. THE CASE STUDY REVISITED

Based upon the enemy's counter-air capabilities Majors

CASEY and MAC could have loaded into the Hornet's computer,

(via a menu driven system on preflight) that the goal of

air-to-air will have priority over that of air-to-ground

from the carrier to the CIP. The aircrew could have also

entered that the priorities of the goals will reverse at the

CIP. Additionally, because of their vulnerability during

the pop up maneuver, the aircrew could input into the system

that the goal of air-to-air must be invoked at all times

should the system detect any enemy air contacts within 25 NM

of the Hornet.

Additionally, the aircrew could have loaded inputs

concerning tasking priorities, aircrew tasking

responsibilities, enemy threats (both ground and air) and threat priorities into the decision support system.

The computer would already "know" such things as what are the DDI displays to be used during the execution of each goal, where the low priority DDI displays are, what the systematic sequence of internal checks are to ensure proper execution of tasks/goal and what are the levels of decision support that it can provide the aircrew.

To continue with the example, as the Hornet flew over the coastal low lands, its ACSS would have sense the enemy's threat radars tracking the aircraft. The ACSS would then have prioritized the levels of decision support that it was capable of providing the aircrew. The system would know (weapons load out inputs) that the F/A-18D was not armed with HARM and consequently had no weapons capable of being immediately brought to bare against the enemy. The only level of decision support available to the system would be Level 3. Radar warning indications would be given and Steering information (to the HUD and the moving map display) would be provided depicting the ACSS's recommended course to steer. This course would be that which the system calculated to take the aircraft out of the enemy's weapon envelopes in the most expeditious manner possible (based upon known and forecast enemy positions).

The example continues. As Majors CASEY and MAC go into the mountains, both aircrew have selected the air-to-ground

radar display on the left DDI, the digital moving map on the center DDI and the navigational FLIR on the right DDI (the pilot still has his HUD). The Hornet's ACSS, picking up the enemy fighters overhead the first bridge and within 25 NM, invokes the goal of air-to-air. The ACSS would first look to see if the air-to-air radar scope was being displayed on any rear cockpit DDI (which would indicate that the task of radar operations was being executed). As this is not the case, the ACSS would provide Level 1 support by replacing the low priority display (as SRTC is not selected the low priority display would be the left DDI) with the higher priority air-to-air radar scope. The system could provide Level 2 support by switching the weapons release mode to air-to-air in order that Major CASEY may fire the AMRAAM should he elect to do so. Additionally, the ACSS could generate Level 3 support by indicating on the moving map display the enemy fighter positions and depict their associated radar coverage envelopes (which have been enter by the aircrew on preflight based upon the threat). Simultaneously, the system would flash a light on the HUD and in the rear cockpit signaling to the aircrew that the ACSS had detected a threat and had updated the DDIs. The system would know that the WSO has been assigned the primary task of conduction radar operations. The ACSS would continue to alert the crew until the WSO, through his hand controls, sent an acknowledgement. The alert signal would

be terminated at this time. The termination of the ACSS's

alert signal would be seen by the pilot on his HUD and

indicate, without any other form of communication being

introduced, that the WSO was aware of the threat and was in

the process of executing his primary task.

III. GUIDELINES FOR TASKING AND COMMUNICATION FLOWS

The last chapter laid the basic foundation of the communication flows and the tasking model that are applicable to the two seat Hornet conducting anti-air and strike warfare missions. It also provided functional requirements to implement a computer-based Aircrew Coordination Support System, ACSS. The focus will now be directed towards establishing general guidelines for communication and aircrew tasking procedures. These aircrew coordination guidelines are generally applicable to any tactical aircraft conducting combat operations without the implementation of a ACSS. Once an ACSS is implemented, these guidelines should still be followed. The ACSS could relieve the aircrew from performing rudementary decision task, however primary tasks still must be accomplished by the aircrew to successfully complete the mission. The purpose of this chapter is to illustrate the usefulness of applying the guidelines. As an example, these guidelines will be applied to the various F/A-18D fighter/attack missions.

A. AIRCREW QUALIFICATIONS

The primary emphasis here is the optimal execution of combat missions. Therefore, the procedures discussed deal

only with experienced, combat ready aircrew who are
executing tasks directly related to combat missions.
Communication and tasking requirements concerning
instructional, administrative or emergency aircrew
coordination procedures will not be discussed here. This
does not lessen their importance; on the contrary, studies
conducted on these communication paths and tasking
procedures should also be the subject of follow on research
projects.

B. STAND ALONE PRODUCTS

The fleet replacement squadron (FRS) is producing what
they call stand alone products/aircrew. The basic
definition of a stand alone product is that each aircrewman
can run all sensors and is proficient at either flying
(Pilot) the aircraft or directing (WSO) the aircraft in a
manner that will most successfully accomplish the assigned
mission or goal. Without realizing it the FRS, by producing
stand alone aircrew, has developed excellent "Degraded mode
procedures" for the two seat Hornet.

Though this thesis is primarily a discussion on the
F/A-18D's primary, sub and supportive tasks and which
aircrew member is best suited to perform each, the
importance of effective degraded operations necessitates a
brief discussion. Should the workstation/cockpit that is
performing the primary task become degraded or inoperative

through system malfunction or battle damage, the remaining
functional cockpit must perform a quick, seamless transition
out of their sub or supportive tasks and into the execution
of the primary task. To ensure F/A-18D combat effectiveness
both the pilot and the WSO must maintain situational
awareness at all times and be continuously prepared should
they be called upon to either assist in or take over the
primary task.

These degraded mode procedures should be briefed and
practiced, both on an actual training flight and during
simulator evolutions, to the greatest extent possible to
ensure that the Hornet's combat performance is not degraded
due to a partial systems failure. An example of practicing
recovery procedures would be to have the TAC LEAD WSO direct
the intercept during a Visual identification (VID) sortie,
vice the TAC LEAD Pilot, though it would be the primary task
of the TAC LEAD Pilot to do so.

C. ADMINISTRATIVE PROCEDURES

Administrative procedures (e.g. the input of data, how
to bring up displays, DDI utilization, etc.) will not be
covered in this research. As previously stated, this study
deals with experienced, combat ready aircrew. For example
it is assumed that, if the pilot is assigned the primary
task of conducting the Air-to-Air intercept against enemy
fighters, he knows how to best utilize the radar's many

43

functions and options. It is also assumed that if an
aircrew is assigned a sub or supportive role that they will
have the display of the primary task, if applicable,
selected in their cockpit in order to maintain situational
awareness and, should the need arise, perform the above
mentioned seamless transition during degraded mode
operations to the primary task.

D. GLOBAL POSITION SYSTEM (GPS)

Currently, the F/A-18D's computer system is not
interfaced with the GPS (position information received from
satellites). System upgrades and software improvements must
provide the Hornet with GPS compatability for three reasons.

First, as the War in the Gulf so vividly bore out, land
combat is not the stagnent lines displayed on combat charts.
In a "Mobile Battlefield", troops can be engaged for
hundreds of miles with no real distinction on boundarys
being drawn. In such situations, unless friendly and enemy
positions are exactly known, the likelyhood of fratricide
caused by friendly air strikes is increased. The GPS could
provide the F/A-18D with exact positions of friendly troops
and thus greatly reduce the possibility of fratricide.

Second, the Gulf War showed that collateral damage
caused by air strikes can generate tremendous political
problems. The GPS would provide the F/A-18D with accurate
target information to aid in the delivery of smart weapons.

Third, a GPS linked directly into the F/A-18D's digital moving map display would aid the aircrew in all weather SRTC operations.

Again, the GPS is not currently installed in the F/A-18D. Because of the reasons just stated, however, it should be incorporated in system upgrades. The last section of this chapter lists the GPS tasks associated with the various Hornet combat missions and which aircrew these tasks should be assigned to.

E. COMMUNICATION GUIDELINES

The fluid nature of combat situations dictates that all cockpit communications must be severely limited. If, however, communications must occur, it should be of short duration. The justification for this is obvious. Much information comes to the aircrew over both external and internal audio paths. To miss one of the information flows, such as a wingman's call to execute a break turn into an incoming enemy fighter, because of excessive internal communications would be disastrous.

For these reasons aircrew, who are in the act of imparting information, should try to execute non computer-mediated communication paths before utilizing computer-mediated communication paths. Additionally, within the non computer-mediated communication category, non-verbal paths (hand signals) should be attempted prior to verbal (spoken)

paths, though this excellent means of communication is severely limited in a fore-and-aft cockpit configuration such as the F/A-18D when compared to its important use in side-by-side cockpits like the A-6E Intruder.

F. TASKING GUIDELINES

As previously stated the goals and tasks (primary, sub and supportive) that aircrew must perform in a combat mission are known prior to the flight. The only question that remains to be answered is "Who should perform what task(s)?" The following are general guidelines on the assignment of primary tasks proposed in this study's tasking model (again, sub and supportive tasks are assigned either when the aircrewman does not have a primary task to perform or in conjunction with the primary task when the work load permits its execution).

All primary tasks either involves maneuvering of the aircraft or the processing of information and they must be assigned to that aircrewman which can execute that task with the least amount of communication flow.

As one would expect primary tasks involving the maneuvering of the aircraft usually are assigned to the pilot. With this assignment the communication flow, either computer-mediated or non computer-mediated, between the pilot and the other aircrewman is eliminated. This allows

for the quickest reaction time and hence greater combat effectiveness.

On the other hand tasks involving the processing of information usually are not assigned to the pilot. The second aircrewman does not have to concern himself with the actual physical act of controlling the aircraft and can dedicate more concentration towards the mental task of "Information processing".

G. F/A-18D MISSION SPECIFIC AIRCREW TASKING PROCEDURES

Each mission of the F/A-18D will be covered separately. The discussion will include a brief description of the goal of the mission, the primary and sub-tasks to be performed, which aircrew is in the best position to execute these tasks and important verbal communication flows. Of course all possible scenarios cannot be covered but mission specific guidelines, concerning tasks and verbal communication flows, is given.

1. Air-to-air: Intercept

The goal of this single aircraft air-to-air mission is to intercept, engage and eliminate the enemy's aircraft(s).

The primary tasks to be performed during an intercept flight are controlling geometry of the intercept utilizing the radar, maneuvering the aircraft to an optimal

firing position and deploying the weapons. All tasks should be performed by the pilot.

Intercept sub-tasks include navigational duties, GPS verification, target identification off of the targeting FLIR (TFLIR), electronic warning (EW) monitoring and visual look-out. The WSO should be assigned primary responsibility for these duties.

The pilot should keep the WSO informed as to his intercept game plan. The WSO should notify the pilot once a positive ID has been made from the TFLIR and provide directive/descriptive commentary concerning sightings of additional enemy aircraft.

2. Air-to-air: Visual identification, VID

The goal of the VID mission is for a Section (two aircraft) of F/A-18Ds to intercept, identify, engage and eliminate enemy aircraft. The two Hornets involved in a VID engagement will be assigned the roles of TAC LEAD and TAC WING. The tasks associate with each role will be covered separately.

The primary tasks of the TAC LEAD aircraft during VID operations are to maneuver/direct the section, control the intercept geometry off of the radar and deploy offensive weapons. These tasks should be performed by the TAC LEAD Pilot.

The TAC LEAD VID sub-tasks, as well as who should perform them, do not differ from those of a single ship intercept.

The TAC LEAD cockpit communication flows do not differ from those of an intercept.

The primary tasks of the TAC WING aircraft during VID operations are to maintain combat spread/mutual support, visual look-out and radar search/sort duties. The task of radar duties should be the responsibility of the TAC WING WSO; all others tasks should be assigned to the TAC WING Pilot.

The TAC WING VID sub-task of TFLIR target identification, navigational duties, GPS verification and EW monitoring should be performed by the TAC WING WSO.

The TAC WING WSO must continuously communicate to the TAC WING Pilot the current air situation (numbers of enemy aircraft, their formation, altitude and distance, etc.) so that, even though the TAC WING Pilot has his head primarily out of the cockpit, he can maintain a mental picture as to the geometry of the VID. The WSO must also pass target ID so that the TAC WING Pilot knows that he is cleared to shoot when the enemy comes within range.

VID verbal communication flows can take place intra-aircraft and inter-aircraft. Directive communications, either to move the section or aircraft, as always would have

priority over descriptive communication and could be given by any aircrewman.

3. Air-to-ground: Day, without enemy fighter opposition

The goal of this air-to-ground mission is to destroy enemy land targets. Section tactics are normally utilized in the execution of these missions and again the two aircraft will be broken down into TAC LEAD and TAC WING.

The primary tasks of TAC LEAD are to control the section, navigate to the target, GPS verification, target acquisition and weapons release. These tasks should be assigned to the TAC LEAD Pilot. Should the F/A-18D upgrade its TFLIR with a laser designator, and should the attack be conducted deploying LGBs, the primary task of target tracking would be assigned to the TAC LEAD WSO.

The TAC LEAD sub-tasks would be to assist in the Section navigational duties, GPS verification, EW monitoring and visual look-out. These are the tasks of the TAC LEAD WSO.

Verbal communication within the TAC LEAD cockpit would be from the pilot describing his intentions or requesting assistance and from the WSO on threat alerts.

TAC WING primary tasks would be to maintain section integrity and mutual support, visual look-out, target acquisition and weapons release. These would be the

responsibilities of the TAC WING Pilot. Again, laser designator upgrades to the TFLIR would necessitate that the TAC WING WSO perform the target tracking duties when employing LGBs.

The TAC WING sub-tasks would be the same as those of TAC LEAD and the TAC WING WSO would perform them.

The TAC WING WSO must provide any threat warnings. Additiona.ly he must verbally paint a mental picture to his pilot of the current status of the flight in order that the TAC WING Pilot may maintain Section situational awareness.

Section communication would include both directive and descriptive intra-flight and inter-flight communications.

4. Air-to-ground: Day, with enemy fighter opposition

The goal of this mission is the same as that of the day strike without enemy fighters. Again, the two aircraft will be broken down into TAC LEAD and TAC WING.

The primary tasks of TAC LEAD are to control the section, navigate to the target, GPS verification, target acquisition and weapons release. The TAC LEAD Pilot should be assigned these tasks. Additionally, TFLIR upgrades and LGB employment would require the TAC LEAD WSO to track the target with the laser designator.

The TAC LEAD sub-tasks would be to assist in the Section navigational duties, GPS verification, radar search,

EW monitoring and visual look-out. These would be the tasks of the TAC LEAD WSO.

Verbal communication within the TAC LEAD cockpit would again be the pilot describing his intentions or requesting assistance and the WSO providing threat alerts (from the radar, EW gear or visual sightings).

The primary tasks of TAC WING would be to maintain section integrity and mutual support, visual look-out, target acquisition and weapons release. These would be the responsibilities of the TAC WING Pilot. As with TAC LEAD, target tracking duties utilizing the TFLIR's laser designator would fall to the TAC WING WSO.

The sub-tasks of TAC WING would be to assist in the Section navigational duties, GPS verification, radar search, EW monitoring and visual look-out. These would be assigned to the TAC WING WSO.

The TAC WING WSO must verbally paint a mental picture to his pilot of the current air situation, but this time he must also include air-to-air descriptive communications.

Section communications would include both directive and descriptive information.

5. Air-to-Ground: Night, visual

The goal of night visual missions is the same as that of day attacks. Night visual strikes differ from day

attacks only in that they require the use of NVGs and a
navigation FLIR. This discussion will center around a
single aircraft mission.

The primary tasks of night, NVG strikes are terrain
avoidance, navigational duties, GPS verification,target
acquisition and weapons release. These should be the
primary responsibilities of the pilot.

Sub-tasks include assisting in the navigational and
terrain avoidance duties, GPS verification, monitoring the
EW gear and radar search if an enemy counter-air threat
exists. The WSO should perform these tasks.

Night visual attacks, especially at low altitudes,
usually requires an increase in verbal communication flows
due to the increased work load. The pilot must immediately
notify the WSO if he is having trouble performing one of the
primary tasks so that the WSO can come off of the
performance of his sub-tasks and assist the pilot. The WSO
must additionally keep the pilot continuously informed as to
the current enemy counter-air situation, if one exist.

6. **Air-to-ground: Night or bad weather, SRTC**

This is a capability that the aircraft does not
possess at this time. For the F/A-18D to become a true all
weather aircraft the following upgrades should be
incorporated. First, the aircraft should be modified by
adding the Global Position System (GPS). The GPS must be

linked directly into the digital moving map display.
Second, upgrades to the radar must be made to allow for a
more detailed picture (either raw or synthetic video) of the
terrain features in front of the aircraft. Third, a
synthetic depiction of the terrain in front of the aircraft
must be projected up onto the pilot's heads up display
(HUD).

The primary tasks during SRTC attacks would be
terrain avoidance, navigational duties, GPS verification,
target acquisition and weapons release. Terrain avoidance,
navigational and GPS verification tasks would be shared by
both the pilot and the WSO. Target acquisition would be the
responsibility of the WSO.

Sub-tasks would include monitoring of the EW gear
and air-to-air radar search (here again I am projecting a
capability that currently does not exist; that being radar
upgrades to allow for the display of both air-to-ground and
air-to-air situation, at the same time, to either cockpits).
The pilot would be assigned these tasks.

The complexity of the communication flows in this
very dynamic and fluid environment would be tremendous.
Information would have to be exchanged based upon the task
that it is associated with (e.g. Primary task information
must be shared before sub or supportive task information).

IV.   GUIDELINES FOR TASK VERIFICATION PROCEDURES

In the previous chapters, we justified the needs of an ACSS. Also, functional requirements as well as mannual tasking and communication guidelines were suggested. However, these guidelines should be thoroughly tested and validated before they can be incorporated in F/A-18D combat missions. This chapter is a broad outline of a basic research design that would evaluate/verify the postulated procedures concerning F/A-18D communication flows and tasking. As one would expect, the setting centers around the F/A-18D Weapons Tactics Trainer Complex (Fig 4.1).

A.   AIRCREW SELECTION

To conduct the validation procedures numerous sets of experienced, combat ready aircrew should be selected from the fleet replacement squadron (FRS) as well as from fleet operational squadrons. Multiple crews would provide a larger pool of data for validation analysis. The objective and subjective flight debriefs of experienced aircrews usually provides a fairly accurate assessment on the conduct of the mission. This would aid the task verification process. Additionally, the multiple crew approach increases the likelihood of finding ad hoc solutions to procedures where the postulated tasking requirement is not correct.
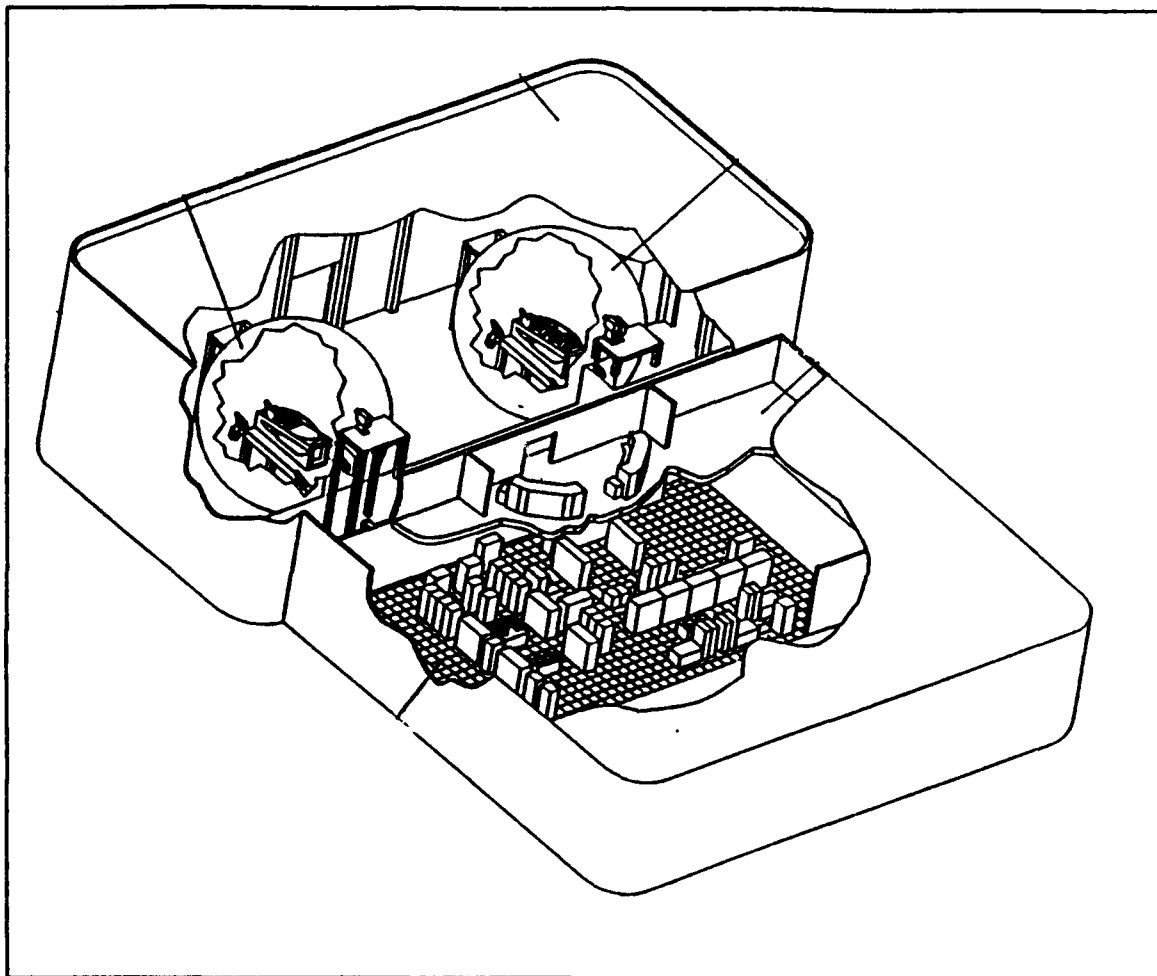
Figure 4.1: Trainer Complex
(Source: WST Operations Manual, 1985)

B. BRIEFINGS AND SCENARIOS

The goal(s) of the flight, with detailed aircrew
tasking requirements, must be thoroughly briefed. It is
imperative that each aircrew know his role is; for we are
trying to evaluate the procedures, not which task each
member individually feels or thinks he should perform.

Each set of aircrew must receive the same mission
scenarios during each phase of testing. Each phase would
cover a different F/A-18D general mission. Phase 1 would
consist of air-to-air missions. Phases 2 and 3 would cover
air-to-ground (Day) and air-to-ground (Night) respectively.
The final phase would require the aircrew to fly an air-to-
ground scenario, with an enroute threat requiring a switch
to air-to-air, then a reversion back to the continuation of
the original air-to-ground mission. These four phases would
test the postulated procedures necessary to achieve the
desired goals. Additionally, because Phase 4 entails the
switching of goals, and hence tasks, these validation
flights would also test the cockpit interface of switching
primary and sub-tasks to successfully complete the mission.

C. DEBRIEF OF PROCEDURES

Debriefing techniques would be open to both subjective
and objective reviews. It is during this phase of the
evaluation process that correct procedures will be
validated, incorrect procedures discarded, and successful ad
hoc procedures identified.

The subjective review would fall along the lines of
aircrew questionnaires and verbal debriefs. Areas of
emphasis would include: Were the tasks identified the
correct ones to achieve the desired goal(s); were the tasks
assigned to the correct aircrewman, etc.

The objective review would be primarily concerned with mission success and did the aircrew adhere to the pre-briefed procedures. Questions concerning aircrew coordination, mission effectiveness and were the goal(s) achieved must be answered as objectively as possible.

An aid in this debriefing process would be the incorporation of a video recording of the various simulator session. The taping of the aircrew coordination would have to take place in the F/A-18D weapons system trainer (WST) or "Delta Dome" (Fig 4.2).

D. VIDEO TAPING F/A-18D TASKING PROCEDURES

The incorporation of video recordings during simulator debriefs will enhance aircrew coordination training. Occasionally, when required to debrief a long flight the clear recollection of things said or done during the "Heat of Battle" is fuzzy or forgotten. This can lead to lost learning opportunities. The old saying "Sweat now so you won't bleed later" is very appropriate concerning simulator training. As a debriefing tool video records will not only reinforce strong practices, but will identify weak procedures in order that they may be eliminated.

Video taping of tandem seat aircrew coordination, conducted in a domed simulator, has never been studied nor attempted. Unlike side-by-side seating, fore-and-aft
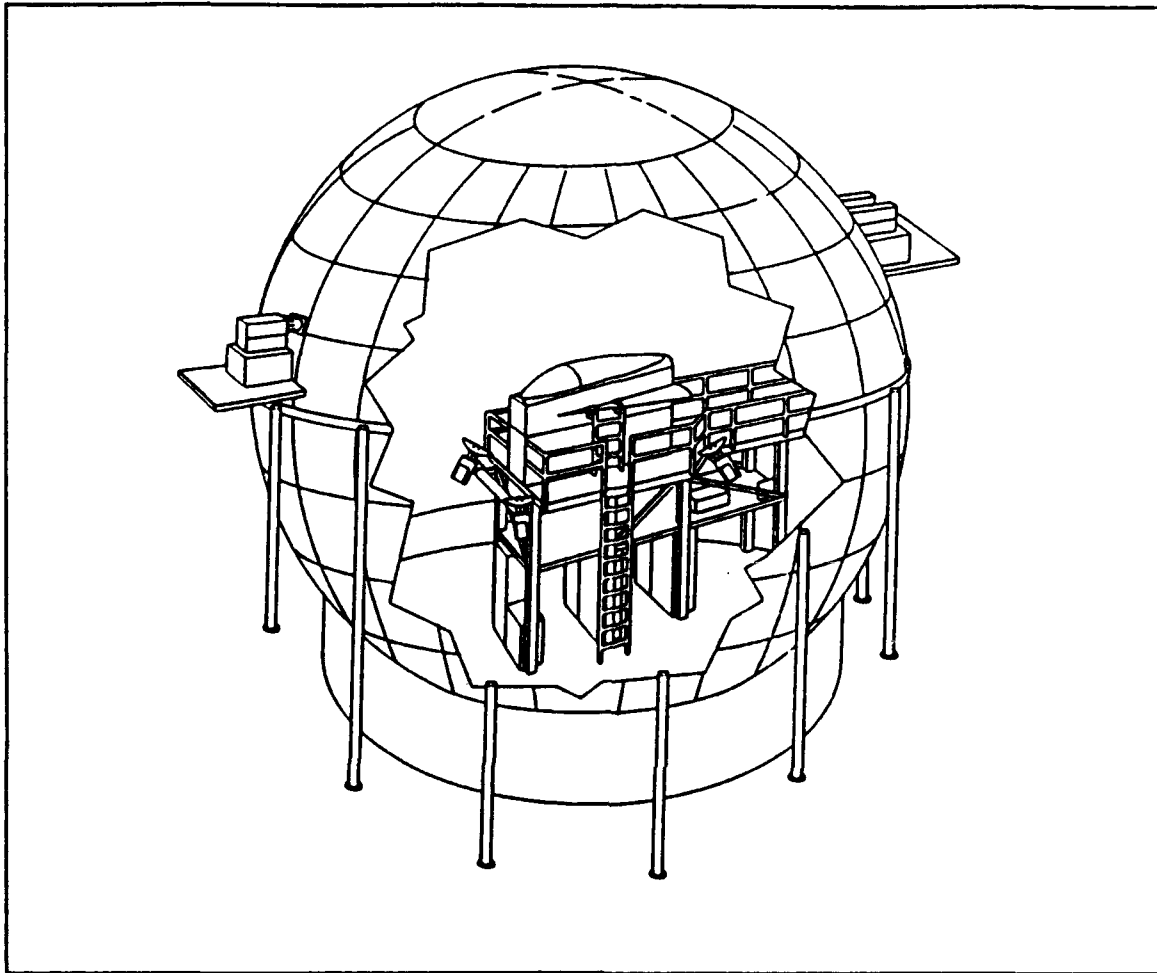
Figure 4.2: F/A-18D "Delta" Dome
(Source: WST Operations Manual, 1985)

cockpit layouts pose some unique problems when it comes to
video taping the coordination procedures of the two
aircrewmen in the seperate cockpits. It is my assertion
that it can be accomplished with the incorporation of the
following ideas into the WST.

First, where should the camera be located. The
location of the camera must be on the dome, aligned with the
cockpit's extended lift vector, between 100 and 110 degrees

rotation up off the extended nose position (Fig 4.3). This view, above and slightly aft of the rear cockpit, will allow for the taping of all aircrew motions within the simulator.
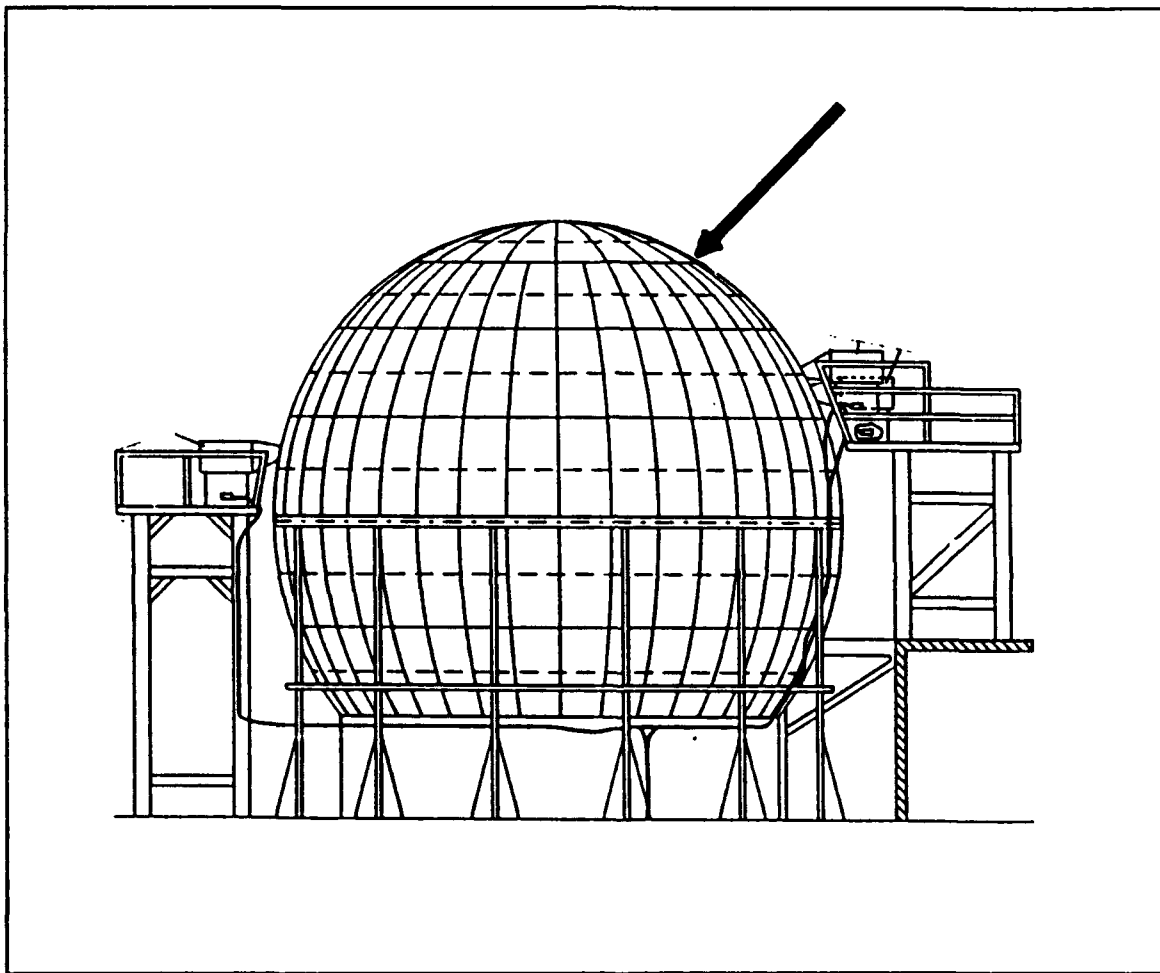

Figure 4.3: Dome Camera Location
(Source: WST Operations Manual, 1985)

Second, the distance between the dome ceiling and the cockpit will require the video camera to have a zoom lens. This camera must also be able to record in the low light levels of the NVG simulated flight scenarios.

Third, video taping of the aircrew coordination procedures must be synchronized with the simulator's computer play-back of the flight. Without this synchronization, the benefit of video record to aircrew debriefs would be greatly reduced.

Lastly, the problem of external glare off of the canopy. Because the camera would be mounted external to the cockpit it would have to shoot through the simulator's canopy. The external canopy glare of day simulated flight scenarios would be too bright, and hence preclude effective video taping of aircrew coordination procedures.

One possible solution to the external glare problems would be to remove the trainer's canopy. This is undesirable for two reasons. First, the canopy does impose confines in which the aircrew must work within. To remove the canopy would introduce an artificiality not found in a F/A-18D. Second, and perhaps more important, the canopy does reflect internal cockpit lighting back into the cockpit. Working with and around this reflected light is especially important during NVG training evolutions. To remove the canopy would remove internal canopy glare and hence introduce an unwanted artificiality during NVG simulator training.

The only workable solution would be to remove the top 80 degrees (40 degrees either side of the lift vector) of the trainer's canopy (Fig 4.4). This action would thus not

only remove the external glare, and hence permit the unencumbered taping of the aircrew, but would still allow for the internal glare off the 50 degrees of each side of the canopy remaining.
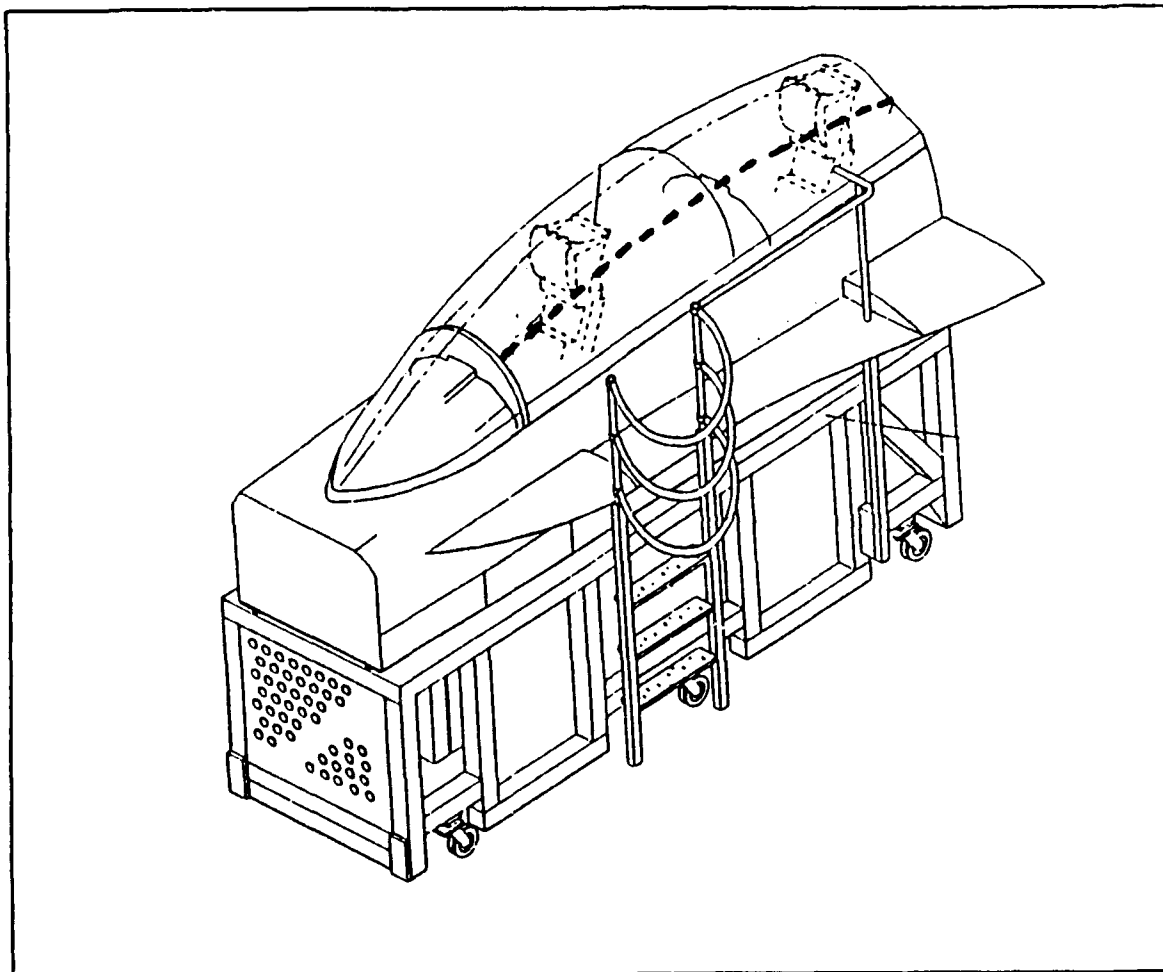

Figure 4.4: Proposed Partial Canopy Removal
(Source: WST Operations Manual, 1985)

V. SUMMARY AND RECOMMENTATIONS FOR FUTURE STUDIES

Chapter V will summarize the focus of this thesis and explore further research topics.

A. SUMMARY

The purpose of this thesis was to define the concept of a Aircrew Coordination Support System (ACSS) that could provide the three levels of decision support to allow the combat aircrew to devote more time and effort in mission-critical decision making.

A discussion of the applicable literature on computer supported collaborative work was presented in Chapter II. In particular, this thesis attempted to apply the "communications module" concept to the F/A-18D's computer support. Functional requirements developed to provide this computer support lead to the determination of the Aircrew Coordination Support System (ACSS).

Chapter III developed guidelines on aircrew tasking and communication flow that must be executed (within or in the absence of an ACSS) to successfully complete combat missions.

Finally, Chapter IV provided one research design to allow for testing and verification of the procedures proposed in Chapter III.

B. FUTURE STUDIES

The focus of this final section is to explore some additional ideas that the study on F/A-18D aircrew coordination has generated and lists likely topics of further research.

1. Combat Vs Instructional Flights

This study has centered around experienced aircrews in the performance of combat oriented missions. Of equal importance would be research conducted on FRS instructional flights.

The thrust of that study would be to examine both administrative and basic combat operational procedures that the FRS instructor must teach/present to the "New" aircrewman (Either pilot or WSO) under instruction. Instructor tasks and communication flows could then be developed. Additionally, ACSS administrative decision support should be explored.

A fine balance exists between an instructor teaching, evaluating and providing constructive criticism of a new F/A-18D aircrewman on the one hand and developing, instructing and generating enthusiastic encouragement of aircrew coordination on the other. There are, in fact, many times when the proper performance of these two tasks would be mutually exclusive. Questions that address and answer such issues as when should an instructor, who is evaluating

a student in the performance of a difficult evolution, stop
the evaluation process and start to develop aircrew
coordination procedures, and hence aid in the discharge of
the task.

A study of the communication flows and tasking
requirements that must transpire in this "Instructional
cockpit" would be most beneficial to the set up of aircrew
training procedures at the FRS.

2. **Extension To Other Aircraft**

Research concerning instructional and combat flights
for other multiplace aircraft, including helicopters and
other VSTOL aircraft, should be undertaken. This
examination would center on communication flows, tasking
requirements and simulator verification scenarios, adapted
from the principles delineated in this study. Research
conducted in these areas will enhance aircrew coordination
procedures and contribute toward improved combat
effectiveness of each aircraft studied.

3. **F/A-18D Simulator**

This study's proposed F/A-18D simulator evaluation
and verification procedures provided only rough guidelines.
Efforts in this area must be undertaken and could be the
subject of numerous research projects.

To effectively teach aircrew coordination, the FRS
must know what to instruct. This study has presented the

many tasks that must be performed to achieve the desired
goals and delineates methods for optimizing individual
crewmember task assignment. But this identification of
tasks is only the first phase, an evaluation process must
then take place to establish their validity. To do this
standard, simulated missions and flight environments must be
developed. Debrief items (questionnaires and techniques),
to include the incorporation of video taping and replay,
must be designed to determine the effectiveness of the
aircrew coordination procedures. Data analysis methods must
be proposed and studied. This is no small task, but one
which must be undertaken if aircrew coordination is to
enhance the capabilities of the F/A-18D Hornet to the
fullest extent possible on every mission.

4. Simulator Debriefs

To enhance the quality of the debrief, a study on
how to integrate the video taping of a F/A-18D simulator
evolution with the WST's computer flight play-back features,
should be pursued.

Areas of emphasis would include: Establishing the
exact position of the video camera on the domed ceiling that
could film all aircrew activity; identification of the video
camera needed to tape the aircrew coordination procedures in
the light levels that would be present during the different
simulator evolutions; generating the interface between the

trainer's computer play back features and the play back of the video tape of the session (to ensure that they are synchronized and provide a realistic reconstruction of the simulator session); establishing the required facilities that would display these two flight reconstruction tools in order to enhance the quality of the debrief session, etc.

The findings of this study would not only be of value in the generation of the required video taping procedures for the F/A-18D simulator, but would also be vitally important in establishing a procedural framework from which the video taping of all other domed simulators could be developed.

5. Aircraft Decision Support Upgrades

A study on aircraft software design changes to upgrade their decision support capabilities should be conducted. This research could either postulate general emphasis areas applicable to all computer supported aircraft or target a specific aircraft type.

First, to lay the foundation for the study and define its scope an examination of the aircraft sensors that are or could be tied into the computer must be undertaken. Then, the systems and displays that are or could be controlled by the computer must be reviewed. The study would then develope around the four modules of the Communications Component model and the three levels of

67

aircraft decision support to postulate areas of software development that would provide this computer support. Emphasis areas would include:

LEVEL 1. What are the display and system selection acts that the aircrew currently perform that the computer system could control upon receipt of external or internal stimuli?

LEVEL 2. What are the set of aircrew actions, concerning display and system selection, that the computer can control and couple with aircrew directive guidance?

LEVEL 3. Does the aircraft possess the necessary sensors that could provide the required input into the computer's logic circuits so that the system may provide the aircrew decision support in the form of directive and discriptive guidance?

Once implemented, such a communications component should significantly enhance the ability of the aircrew to conduct higher levels of combat tactical thought and decision making.

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